Multiple Modes In Science Instruction: Diversifying Opportunities For Students To Learn

By: **Rachel Wilson** and Leslie Bradbury

Abstract

To become scientifically literate, students need to interpret science concepts using numbers, text, and visuals. Scientists use multiple modes to communicate their ideas to each other and the public, including images, text, mathematical notations, symbols, diagrams, charts, and graphs. Several of the science and engineering practices in the Next Generation Science Standards incorporate multiple modes of representing information: developing and using models; analyzing and interpreting data; using mathematical and computational thinking; and obtaining, evaluating, and communicating data. Here, Wilson and Bradbury discuss the benefits of multiple modes in science instruction and how teachers can incorporate them in their teaching.

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Multiple Modes in Science Instruction

Diversifying Opportunities for Students to Learn

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To become scientifically literate, students need to interpret science concepts using numbers, text, and visuals (Lemke 2004). Scientists use multiple modes to communicate their ideas to each other and the public, including images, text, mathematical notations, symbols, diagrams, charts, and graphs. Several of the science and engineering practices in the *Next Generation Science Standards* (NGSS Lead States 2013) incorporate multiple modes of representing information: developing and using models; analyzing and interpreting data; using mathematical and computational thinking; and obtaining, evaluating, and communicating data (see Table 1, p. 78). In the suggested targets for the Grades K–2 and 3–5 bands, students should be able to interpret science information presented in multiple modes to build their scientific communications skills.

In addition, using multiple modes in science instruction allows teachers to integrate other subject skills within a science unit, such as English language arts standards for reading, writing, and speaking and mathematics standards for numbers and operations and measurement and data. When we integrate subject skills, science becomes more relevant for students.

Furthermore, having facility with multiple modes of representation in science instruction benefits student learning and increases their depth of understanding (Wilson and Bradbury 2016). Elementary learners can convey different types of information depending on the mode. For example, drawings and physical models are better able to convey information about structures and components, while in writing and speaking, students are more likely to convey process information (Wilson and Bradbury 2016). Additionally, as students use and produce information in various modes, they transfer information from one format into another, which deepens their learning.

Finally, science instruction presented in various modes can provide greater access to science information for all students. Elementary learners with learning disabilities, English language learners, and struggling readers and writers all benefit from the use of visual modes of representation to understand texts (Adoniou 2013; Taylor and Villanueva 2014). Drawing a process before writing about it allows English language learners (ELLs) to increase their use of academic language vocabulary (Adoniou 2013). Drawing also provides ELLs an alternate and concrete way to communicate their understanding if they are still developing vocabulary. Allowing students with learning disabilities to document science investigations or results with photographs and drawings helps them record and interpret their experiences with science content (Taylor and Villanueva 2014). The use of visuals also helps struggling readers and writers create meaning from science experiences and increase their understanding of science content (Wilson and Bradbury 2016).

TEACHING WITH MULTIPLE MODES OF REPRESENTATION

Using Multiple Modes to Present Science Content

As science teacher educators, we spend time in elementary classrooms with our undergraduate and graduate students and work with inservice teachers to improve their science teaching. In our own planning and teaching experiences in elementary classrooms, we think about how many different ways we can present science content information to students. In a unit on sound, for example, graduate students worked with one of the authors to prepare and facilitate activities that incorporated multiple modes of representing science content to help students visualize, feel, and read about the content. Elementary students worked with tuning forks, a homemade salt drum, Boomwhackers (plastic tubes at varying lengths that make notes when hit on the ground or table), and glass bottles with varying amounts of water to help visualize how forces create sound through vibrations. For each of these activities, students could see how their force caused vibrations that resulted in a

sound. In the case of the salt drum, this vibration was passed to the salt, which they could see vibrating on top of the plastic wrap. To support the visual information from hands-on activities, students also viewed multiple videos to see relevant examples of sounds in animals, such as a rattlesnake, a bullfrog, and a cat chattering, as well as watching "oobleck" (a cornstarch and water non-Newtonian fluid) vibrate as it sat on a speaker playing music. Finally, students used an app called Sound Wave TW Recorder to visualize sound waves that the app makes when sound is made near the tablet.

In addition to visual experiences with sound and vibrations, students also were able to feel the tuning forks and plastic rulers vibrating as they

TABLE 1.

***NGSS* practices and modes of science instruction.**

SCIENTIFIC AND ENGINEERING PRACTICE	DESCRIPTION OF PRACTICE	MODES REFERENCED IN *NGSS* DESCRIPTION OF PRACTICES FOR GRADES K-5
Developing and Using Models	In science, models are used to represent a system (or parts of a system) under study, to aid in the development of questions and explanations, to generate data that can be used to make predictions, and to communicate ideas to others. (Appendix F, p. 6)	Diagrams, drawing, physical replicas, diorama, storyboard, mathematical representations, analogies, dramatization
Analyzing and Interpreting Data	As students mature, they are expected to expand their capabilities to use a range of tools for tabulation, graphical representation, visualization, and statistical analysis. Students are also expected to improve their abilities to interpret data by identifying significant features and patterns, use mathematics to represent relationships between variables, and take into account sources of error. (Appendix F, p. 9)	Drawing, writing, graphs, maps, charts
Using Mathematics and Computational Thinking	Students are expected to use mathematics to represent physical variables and their relationships and to make quantitative predictions. (Appendix F, p. 10)	Numbers, graphs, charts
Obtaining, Evaluating, and Communicating Information	Being able to read, interpret, and produce scientific and technical text are fundamental practices of science and engineering, as is the ability to communicate clearly and persuasively. (Appendix F, p. 15)	Text, media, diagram, drawing, writing, numbers, tables, charts,

hit them and held them on the table, and students were encouraged to hum or speak while feeling their Adam's apple, or laryngeal prominence, so that they could feel their vocal cords vibrating. Then, they were given two wire baskets tied together with a string and wrapped their finger in the string and placed their fingers in their ears. Their partner was then encouraged to tap the basket with a pencil and gently bang the basket on the side of a table. The elementary students also learned how to use gestures to support their understanding of the word *vibration* (moving both hands back and forth toward each other) and a dramatization of particles passing on a sound wave, or vibration. These embodied experiences, or physical representations, helped support the visual representations.

Similarly, presenting multiple modes in science content is just as adaptable to Earth science topics as it is to physical science topics. In a unit on weather, for example, elementary students used purchased weather tools and built their own tools during an investigation. Students made their own alcohol thermometers and then tested them in warm and cool water baths to observe how the temperature affected the level of the alcohol in the straw. They then compared their thermometer with both a vertical and round thermometer that had been placed outside their classroom. In addition, students constructed a wind vane, an anemometer, and a rain gauge after viewing photographs and videos of these tools on a web board. They used their own constructed tools and purchased tools to make visual observations of weather, recording both qualitative descriptions of weather from their own tools and numerical observations from the purchased tools.

In addition to the visual representations, elementary students physically experienced the phenomena. When observing the weather, they not only used their eyes but also could feel the wind and temperature outside. These visual and physical experiences of science content were supported through the use of informational text that we created on a website to complement the photographs and videos of weather tools, describing how the instrument worked.

Students Using Multiple Modes to Show Science Understanding

Using multiple modes in science instruction allows students to communicate their understanding of content. As teachers, we recognize the benefits of allowing students multiple avenues for representing their ideas (Adoniou 2013; Wilson and Bradbury 2016). The benefits of allowing students to draw as one component of their assessment, or even in preparation for a written assessment, allows students the opportunity to showcase different types of information (Wilson and Bradbury 2016), and it acts as a scaffold for their writing (Adoniou 2013). Drawings can be particularly helpful when students have not yet learned academic language that will help them communicate their understanding via writing.

As a way to focus student attention, we ask students to record their observations during science activities. For example, after students constructed their thermometers and tested them with their hands and in two different temperature water baths, they were asked to write their observations of what the thermometers looked like in the warmer bath vs. the cooler bath (Figure 1). These writings were recordings of the observations that could then be used as a scaffold for the development of science concepts, such as how their thermometer was similar to and different from the thermometers used to measure the air temperature outside of their classroom.

FIGURE 1

Student predictions of alcohol thermometers.

Alcohol Thermometers

Predict what you think will happen in each experiment. Do you think the liquid in the straw will rise, fall, or stay the same? Why?

Condition	Prediction	Result
Hands	I think it will stay the same. Because it is cold.	The heat from our hands made it rise.
Ice Water	I think it will fall.	The liquid in the straw fall down.
Hot Water	I think it will rise because the water is very hot.	The liquid straw will rise beacas the water is hot.

We also routinely ask elementary students to draw a concept, process, or structure with added text labels as a scaffold for their writing about it. In this way, they can record information they know in a more visual format before being asked to translate this representation into words. In the weather unit, students were asked to draw a wind vane and write observations of how their tool worked (Figure 2). In the sound unit, students were asked to draw their activities at their various centers (wire rack, tuning fork, and bottles with water) (Figure 3). In the sound unit, students were also asked to construct arguments about what they knew about sound based on their explorations in the centers (Figure 4). They were supported in writing claims, evidence, and reasoning statements using the data they collected in their hands-on activities to support their claims about sounds. Therefore, the experiences of recording their observations using drawings and writing prepared them for writing intensive conclusions at the end of the unit.

Planning for Multiple Modes of Representation

When planning to incorporate multiple modes of representation in your teaching, you can start with a lesson plan or a unit plan. In our planning with classroom teachers, we think about the resources already available to them in their classroom (often physical materials and text), and then brainstorm what ways they vary the representations of content they use with students. McDermott and Hand (2015) suggest the development of a checklist with K–12 students to evaluate science communication. The purpose of such a checklist is to help students see how many modes are used in communication about a science idea, how text is integrated with other modes, and how the piece is constructed for its audience. In our work with preservice and inservice teachers, we constructed a checklist to help teachers evaluate the representations they're choosing and using in their classroom teaching (see NSTA Connection). For example, this checklist helps teachers in their planning to strategize which modes are already present in their teaching and can help them target modes they may not be used to incorporating.

Often, some content is hard to represent due to the timescale of a process, the size scale of an object under study, or safety or ethical issues related to observing a process or organism in person. When these situations occur and we know that observing a phenomenon or organism will help students conceptualize a concept, we look for freely available videos or photographs. In a Google

FIGURE 2

Student drawing of a wind vane with their observations.

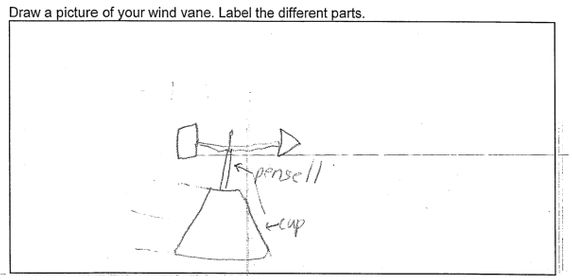

FIGURE 3

Student drawings and observations.

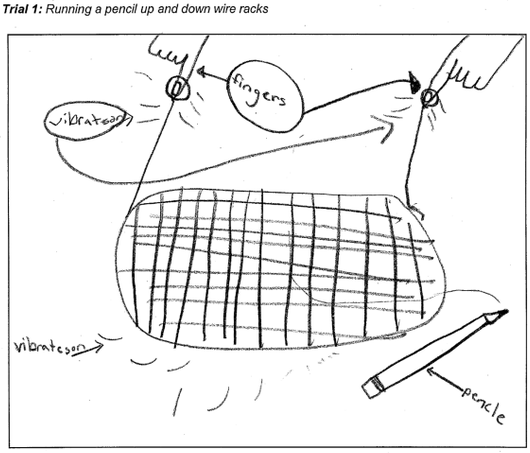

FIGURE 4

Student summary.

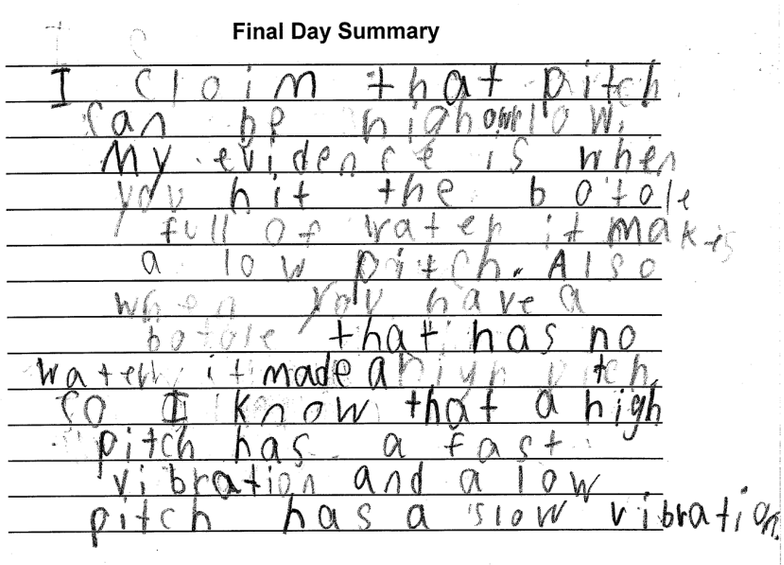

image search, you can customize your search using the Tools option, and then search for images or videos by entering "labeled with usage rights for non-commercial reuse," so that teachers can use resources without gaining copyright permissions. We often use these types of resources on teacher-created web pages to showcase different visual representations for students to use during a unit.

NSTA Connection

Download the checklist at *www.nsta.org/sc1908*.

CONCLUSION

Whether you have practiced or are new to integrating multiple modes of representation into your teaching, we have found this checklist to be a helpful aspect for planning. Integrating diverse representations of content throughout a unit of study helps all learners develop deeper understanding of science ideas and makes the learning environment much more stimulating. By representing content in multiple ways, we maximize the opportunities for students to learn. ●

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